



World Scientific News

WSN 58 (2016) 84-96

EISSN 2392-2192

Quinoa (*Chenopodium quinoa* Willd), functional superfood for today's world: A Review

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ABSTRACT

Quinoa (*Chenopodium quinoa* Willd) was known to the Incas as “the mother of all grains” and was believed to be sacred. It has been consumed in the form of food as well as medicine for the last 5000 years. Quinoa, a pseudo cereal, is recognized as one of the world's healthiest foods due to its high nutritional value along with its potential to cater various health benefits. Being a good source of complete *protein* (contains all the nine essential amino acids), unsaturated fatty acids, minerals, vitamins, fibre and antioxidants, it is considered as “superfood”. Quinoa also helps to reduce the risk of various diseases like cardiovascular diseases, type-2 diabetes, some cancer, high blood pressure, obesity and is also a good option for people who are allergic to certain food groups. Its biodiversity and ability to sustain in adverse climatic conditions makes it an ideal crop to cultivate worldwide especially in under developing countries of Asia and Africa, where food production is threatened by global climatic changes. Hence, it is a demand of present world to increase the awareness regarding the various functional benefits of quinoa to combat one of the world's major crises, that is, hunger and malnutrition.

Keywords: Quinoa; Pseudo cereal; Healthy food; Antioxidants; Glycemic index

1. INTRODUCTION

In present world, food security and good health has become one of the major important issues in all countries especially the developing countries. Due to ongoing change in our ecosystem and different climatic changes, lot of pressure is on reliable food production to provide good health to the world's growing population. In present era, about 1 in 8 individuals already suffers from chronic undernourishment. Along with that, diabetes, obesity and other metabolic disorders have also reached global epidemic proportions [1,2].

Earlier lots of diseases which were believed to be caused by single gene mutation, are now believed to be caused due to a network of biological dysfunction and food which we eat is an important factor in that dysfunction. It is a well-known fact that food which we intake provides nutrients to our body, that they need to function properly. If proper food is not taken our metabolic process suffers and health declines which leads to the onset of various diseases. Traditional, foods are increasingly considered healthy and wholesome, and as a result, public interest in their nutritional and functional aspect has increased along with their demand. Functional foods are similar to conventional foods alongside providing certain health benefits beyond basic nutritional functions.

Cereal based food provides 30-70 percent energy the human needs every day. This emphasize the scope of using cereal grains or cereal grains like more other functional foods for consumption. Quinoa is one such food gaining popularity nowadays.

Quinoa is a species of the goosefoot genus. It's a crop grown primarily for its edible seeds. Being high in various important nutrients, it is considered as world's one of the most popular health foods. The Food and Agricultural Organization of the United Nations (FAO) officially declared the year 2013 as "The International Year of The Quinoa". FAO declared quinoa as a food with high nutritive value, vast biodiversity and as a food which can have an important role to play in the achievement of food security worldwide [3]. Being highly nutritious, quinoa also imparts various health benefits which makes it an excellent example of 'functional food' as suggested [4].

2. HISTORY OF QUINOA

Quinoa was known to the Incas as "the mother of all grains" and was first cultivated over 5000 years ago. It was considered as a gift from their gods and was even used for medicinal purposes. It was staple for the Incas and is still a prominent food source for their indigenous descendants, the Quechua and Aymara people. The legends states that the first quinoa seeds were ceremoniously planted every year by the Incas emperor.

Earlier, quinoa seeds were added to soups, used as cereal and was even fermented into beer or chichi (traditional drink of the Andes) [4,5]. Traditionally, widely consumed in the highlands of the Andes in South America, quinoa has attained popularity as health food in North America, Europe, Australia, Japan and India [6]. Today, quinoa is presently cultivated or tested in 95 countries of the world as mentioned [7]

3. BOTANICAL DESCRIPTION AND CULTIVATION OF QUINOA

[8,9] Quinoa termed as “pseudo cereal” belongs to the family of Amaranthaceae (previously Chenopodiaceae). The quinoa seeds contain a central perisperm where carbohydrate reserves are localized which is surrounded by protein and oil rich embryo, endosperm and seed coat. The pericarp of the fruit contains saponins, a bitter substance, which can be removed either by washing or by mechanical abrasion. This de-saponification process is also called dehusking [10], pearling [11] or milling [12]. Due to its nutritional makeup, it is included in the “whole grains” category[13]. One of the main advantage associated with quinoa unlike the other cereal grains where the processing of the grains takes away the germ and bran part which is nutrient rich, de-saponification of quinoa leaves the nutrient rich embryo and endosperm intact [14].

Quinoa is drought resistant, and grows well on poor soil without irrigation and fertilizers. Quinoa is considered as a chief crops under rain-shadow highlands of Bolivia, Peru, Chile and Ecuador since ancient times. Quinoa grows about 3 to 9 feet tall on magenta stalks. It begins flowering in July which subsequently develops into edible seeds (2-3 mm in diameter) by the end of August through September. About half pound of seeds can plant a full acre, yielding 1200-2000 pounds of new seeds per acre. Because of its potential to feed hungry poor population, United Nations has designated it as a “super crop” as it is not only rich in nutrients, it can also survive in adverse climatic conditions [15].

4. NUTRITIONAL AND FUNCTIONAL PROPERTIES OF QUINOA

Consumption of quinoa not only provides various nutrients to our body but also contributes to various health benefits. It is a great food not only for vegetarians or vegans but also for people who want to cut down the intake of cholesterol, sugars and add more health beneficial nutrients like protein, good fat, certain important vitamins, minerals and fiber.

Table 1. Nutritional facts about quinoa.

Nutrient Facts Serving Size: 1 cup (170 gram)	
Amount per serving	% Daily Values
Calories 626	Calories from Fat 93
Total Fat 10.3 gram	16 %
Saturated Fat 1.2 gram	6 %
Polyunsaturated Fat 5.6 gram	
Monounsaturated Fat 2.7 gram	
Cholesterol 0 mg	0 %

Sodium 9 mg	0 %
Potassium 957 mg	27 %
Total Carbohydrates 109.1 gram	36 %
Dietary Fibre 11.9 gram	48 %
Protein 24.0 gram	
Vitamin A 0 %	Vitamin C 0 %
Calcium 8 %	Iron 43 %

Based on a 2000 calories diet. [16]

4. 1. Protein

Quinoa is one of the most protein rich foods we can eat. The biological protein value measures the proportion of protein absorbed from a food which then becomes incorporated into the proteins of the body. Quinoa has high biological value (73%), similar to that of beef (74%) and higher than those of white rice (56%), wheat (49%) and corn (36%) [3].

The protein quality of quinoa is even comparable to the high quality protein from the dairy products, called casein [17-22]. Since it contains all the nine essential amino acids, it is considered as a complete protein rich food. When most of the grains lack adequate amount of amino acids lysine and isoleucine then quinoa has significantly greater amount of both lysine and isoleucine (especially lysine), which allows quinoa to serve as complete protein source [6].

Table 2. Amino Acids and Protein in quinoa [21]

Essential Amino Acids	Quinoa mg/g protein
Methionine and Cysteine	21
Lysine	51
Tryptophan	8
Valine	45
Threonine	30
Phenylalanine and Tyrosine	74

Histidine	25
Isoleucine	37
Leucine	64
Total	100 %

4. 2. Lipids

A higher intake of vegetables is associated with a reduced risk of type 2 diabetes, due to their high unsaturated fat content, which is associated with lower inflammation [23,24]. Quinoa is considered as a valuable source of certain health supportive fats. About 28 % of quinoa’s fatty acids is oleic acid, a monounsaturated fat, which is good for heart and about 5 % comes as alpha-linolenic acid, the omega-3 fatty acid, associated with decreased risk of inflammatory diseases [6]. A lower ratio of omega-6: omega-3 fatty acids are more desirable for reducing the risk of cardiovascular diseases, cancer and inflammatory, and autoimmune diseases. The ratio between omega-6 and omega-3 fatty acids in quinoa is about 6:1 [4,25].

4. 3. Minerals content

If we consider today’s eating pattern, it can be observed that the diet of people lacks in many nutrients, particularly some very important minerals like magnesium, potassium, zinc and iron. The lack of iron is one of the most common nutrition deficiencies. It keeps our red blood cells healthy and carries oxygen from one to another cell and also increases brain functions along with another important functions in our body.

Similarly, magnesium helps to relax blood vessels and thereby to alleviate migraines. It may also reduce Type 2 diabetes by promoting healthy blood sugar control along with providing other health benefits [26]. Zinc is a cofactor in many enzymes that regulate growth and development, sperm generation, digestion and nucleic acid synthesis.

Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. Quinoa is a good source of calcium, iron, potassium, magnesium and zinc when compared to daily mineral recommendations. It can be said that on an average quinoa is a better source of minerals than most grains as shown in the table.

Table 3. Mineral content of quinoa and selected foods, mg/100g dry weight [27].

Minerals	Quinoa	Maize	Rice	Wheat
Calcium	148.7	17.1	6.9	50.3
Iron	13.2	2.1	0.7	3.8
Magnesium	249.6	137.1	73.5	169.4
Phosphorus	383.7	292.6	137.8	467.7

Potassium	926.7	377.1	118.3	578.3
Zinc	4.4	2.9	0.6	4.7

Although, one problem associated with quinoa is that it also contains a non- nutritive component called phytic acid, which can bind with the minerals and reduce their absorption. However, by soaking and/or sprouting quinoa before cooking, phytic acid content can be reduced and the minerals can be made more available. Quinoa also contains saponin, which taste bitter, could cause gastric irritation. Its content varies between 0.1-5 percent. These are found on the outer layer of quinoa seed and are usually removed during processing. It is observed that without any significant modification of nutritional value, saponins can be removed by thorough washing in cold water [28]. Quinoa is also high in oxalate which reduce the absorption of calcium and magnesium and can cause problem in certain individuals having kidney stones [29]. However, cooking of quinoa reduces the oxalate content.

4. 4. Vitamin content

As compared to other grains, quinoa is also a good source of B vitamins riboflavin and folic acid. Riboflavin improves energy metabolism within brain and muscle cells, and folic acid plays crucial role for proper brain function and is important for good mental and emotional health. It is very important vitamin for pregnant women as it lowers the risk of neutral birth defects [30]. Quinoa also contains significant amount of vitamin E, which acts as antioxidant, although the quantity declines after processing and cooking [27].

Table 4. Vitamin content of quinoa and selected foods, mg/g dry weight [27].

Vitamin	Quinoa	Maize	Rice	Wheat
Thiamine	0.2-0.4	0.42	0.06	0.45-0.49
Riboflavin	0.2-0.3	0.1	0.06	0.17
Folic acid	0.0781	0.026	0.02	0.078
Niacin	0.5-0.7	1.8	1.9	5.5

5. SOME OTHER FUNCTIONAL PROPERTIES OF QUINOA

5. 1. High in antioxidants

Compounds known as reactive oxygen species are produced in the body in response to environmental pollutants, cigarette smoke, sunlight, oxidized compounds in foods and certain metabolic processes, which cause oxidative damage in cells of the body. This can in turn trigger chronic diseases and conditions, including cardiovascular diseases, cancer and diabetes. Antioxidants appear to combat this oxidative damage.

Quinoa contains good amount of polyphenols which act as antioxidants. Quinoa has 23 phenolic compounds. The total phenolic content (mg/kg quinoa) is 466.99, 634.66 and 682.05 for white, red and black quinoa respectively. Ferulic acid and quercetin are most abundant phenols found in quinoa [31-33]. In fact the quercetin content of quinoa is even higher than typical quercetin rich foods like cranberries [30]. From researches it has been found that allowing the quinoa seeds to sprout seems to increase the antioxidant content even further [34].

5. 2. High Fibre content

Another very important benefit of quinoa is that it is high in fibre content. It contains almost twice as much fibre as most other grains. Fibre not only helps relieve constipation, it also helps prevent heart disease by reducing high blood pressure and diabetes. Fibre also reduces cholesterol and glucose levels along with lowering the risk of developing hemorrhoid and helps lose weight. One study that analyzed four varieties of quinoa found a range of between 10-16 g of fibre per 100 g [35]. It is observed that cooked quinoa consist of mostly insoluble fibres (80-90 percent). Studies has shown that some of these insoluble fiber may be fermented in the gut like the soluble fibres, feeding the friendly bacteria and promoting better overall health [36,37]. One Cup of cooked quinoa contains 21 percent of the recommended daily intake of fibre. Quinoa is also more easily digestible than many other grains according to World's Healthiest Foods [38].

5. 3. Gluten free

According to a 2013 survey, about one-third of the population of United States are either trying to minimize or avoid gluten intake. Celiac disease is a genetic autoimmune disorder where the ingestion of gluten leads to damage in the small intestine. It is estimated to affect 1 in 100 people all over the world. If untreated it may lead to various additional health problems like iron deficiency anaemia, osteopenia, infertility, lactose intolerance and only treatment for this disease is lifelong adherence to a strict gluten free diet [39-41]. Many researchers are considering quinoa as a suitable ingredient in gluten free diet especially for those people who don't want to give up staples like breads and pasta. Studies have shown that by using quinoa as a substitute of gluten free ingredients like refined tapioca, potato, corn and rice flour, it can increase the nutrient and antioxidant value of the diet many folds [42,43].

5. 4. Low glycemic index

Glycemic index is a measure of how quickly foods raise blood sugar levels. Using a scale of 0-100, glycemic scores are separated into three groups- low, moderate and high. Any food with a score of 55 or less falls in the low glycemic range, 56-69 in moderate and 70 or above in high glycemic category. Low glycemic index food improves glucose and lipid levels and weight control. They also reduce insulin resistance and risk of cardiovascular diseases, diabetes and some cancers [23,44]. Quinoa has glycemic index score of 53, based on a 150g serving, or a little less than 1 cup of cooked quinoa as it contains 32g of total carbohydrate, including 1 g of sugar. Since most of these carbohydrate comes from starch, a complex carbohydrate, these digest slowly hence enter the bloodstream gradually thus avoiding harmful blood sugar spikes [45].

6. ALLERGENICITY RELATED TO QUINOA

It is not a commonly allergenic food since it does not belong to the plant family, containing wheat, oats, barley, and rye, it is gluten free food. It can be ingested by people who have allergies against wheat protein [46]. Quinoa makes a good option for anyone diagnosed with celiac disease. But any food that is initially introduced to the body can likely trigger an allergic reaction. After the consumption of quinoa, the immune system might mistake the proteins in quinoa as a harmful substance and might produce allergic reactions. However, in lot of these cases, improper preparation tends to be the cause of the problem. Therefore, most important step in the preparation is to rinse the seeds thoroughly under a running water to remove saponin, before cooking quinoa.

7. QUINOA IS A CULINARY TRIPLE THREAT

Visualizing the enormous health benefits of quinoa and knowing the fact that it is very nutritious, gets easily incorporated into our diet, as it goes well with many foods and it is easy to cook, therefore it is highly recommended to make it a part of our diet. A study at Harvard Public School of Health had found that eating a daily bowl of quinoa reduces the premature death from cancer, heart diseases, respiratory diseases and diabetes by 17 percent.

8. SHELF LIFE OF QUINOA

Shelf life of quinoa is affected by various factors like whether it is cooked, uncooked or how it is stored.

Table 5. Quinoa expiration date [47].

Raw	Pantry (past printed date)	Refrigerator (past printed date)	Freezer (past printed date)
White quinoa lasts	2-3 years	2-3 years	-
Red quinoa lasts	2-3 years	2-3 years	-
Black quinoa lasts	2-3 years	2-3 years	-
Cooked			
Quinoa lasts for	-	6-7 days	8-12 months

Like any other food grains, best way to store quinoa is in an airtight container in the pantry or another cool dark place with a constant temperature. Like any other cooked food, cooked quinoa should not be kept at room temperature for more than 2 hours for its best taste. Cooked quinoa can be refrigerated in an airtight container as well as they can be frozen also to

enhance the shelf life. Like lots of other food grains, it usually has a best by date and not an expiration date. That is why, it can be safely used beyond the stamped best by date, if kept in freezer.

9. COOKING OF QUINOA

Now a days quinoa is available in many supermarkets and health food stores. Some brand quinoa are already rinsed and then packaged, otherwise it is important to rinse it to get rid of antinutrient saponin, found in outer layer, to avoid bitterness. There are hundreds of recipes of quinoa. It can be served as breakfast porridge. Quinoa can be used in salad by combining cooked chilled quinoa with pinto beans, scallions and coriander. By using quinoa noodles instead of regular wheat or rice based noodles, gluten free and highly nutritious pasta recipe can be made. Quinoa flour can be used to replace the regular refined flour to make cakes and biscuits. Quinoa can replace rice in any “stuffed” veggie recipe because not only it will provide almost 16 percent of our daily iron value compared to brown rice it is also laden with lots of other vitamins and minerals. It can be used to make veggie burgers by using quinoa patties. Half cup of cooked quinoa with one cup of beans will give the same serving size. Quinoa can be used to substitute bread crumbs in meatloaf recipe, to help bind the ingredients together. This will give bread a nutty flavor and texture [48].

10. CONCLUSIONS

In recent past few years quinoa has gained popularity- all the way from back shelves of health food stores to supermarket aisles. Incorporation of quinoa in our diet not only increases the nutritive value but will also reduce the risk of various health diseases like cardiovascular diseases, type 2 diabetes, high blood pressure, cancer, obesity. Quinoa is also a gluten free alternative food available for celiac patients. Being highly nutritious, quinoa can be used to complement the diet of those population who are suffering from malnutrition, are allergic to certain food groups or are purely vegans.

The only main anti- nutritional factor associated with quinoa is saponin, a water soluble phytonutrients, which can be reduced by washing, soaking, boiling of quinoa.

Use of quinoa represents a promising area of research as its use in our daily diet can improve the intake of certain important nutrients and phytochemicals which caters important health benefits.

More emphasis should be given to its cultivation, distribution and proper preparation to overcome the hunger and undernourishment problems of different parts of the world, especially the developing countries like Asia and Africa where food production is threatened by global climate change.

Finally, it can be concluded that by increasing the awareness regarding quinoa’s biodiversity, ability to sustain in different cultivation methods, its various culinary uses and most important its ability to cater enormous health benefits, the improvement in health condition of large segment of poor population of this world can be improved.

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(Received 12 October 2016; accepted 30 October 2016)